Assessment of Dual Culinary Use Potential of Common Bean Landraces in Sustainable Agriculture

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Abstract

A representative group of 100 common bean (*Phaseolus vulgaris* L.) landraces from different bean areas of production in Spain and six elite cultivars were evaluated for agronomic and quality traits in three environments. The objective was to assess the potential for dual culinary uses (DCU) of common bean landraces for vegetable and grain products. Most landraces studied had aptitude to be used primarily as dry beans although landraces showed wide variation in some attributes related to seed and pod quality. Principal component analysis permitted ordination of the landraces according to variation in seed and pod traits. Two snap bean groups arose from the analysis, named as Group 1 and Group 2. Seven bean accessions recognized previously as dry bean types were assigned to Group 1B, inside Group 1. They displayed adequate scores for pod traits (pod fiber, pod length) to be used as snap beans. This fact indicates the presence of landraces with DCU potential in particular areas of production in the Northwest of Spain. This finding is relevant for breeding and common bean production since farmers could have two different products from the same crop using traditional cultivars. Potential dispersion of these cultivars to areas where sustainable farming is desired should merit further research effort. From the point of view of breeding, DCU landraces should be useful as a starting point since this germplasm is adapted and possesses valuable characteristics for pod and seed quality.

Introduction

Common bean is consumed in many different forms. Dry beans as a protein source in human diets is the most frequent use, but other forms have also importance. Thus, the pods are consumed in the fresh, preferably fiberless state, called snap bean, French bean or green bean. Snap beans are assumed to have originated in North America and Europe through selection of mutations for pod quality characteristics such as lack of pod fiber. According to Atkin (1972), the first stringless varieties of beans were released in the US from selections within Refugee Wax and German Black Wax in 1887.

Genetic differences among varieties selected for use as fresh pod or dry seed are not probably wide enough since few genes are responsible for the phenotypes that produce edible pod in bean varieties. In fact, the improvement of snap bean to obtain new cultivars that incorporate desired pod characteristic into adapted genotypes includes the use of dry bean cultivars as the main source of germplasm (Myers and Baggett, 1999). Seed color and size are relevant traits for dry use of bean since they are important to define the market classes (Santalla et al., 2001) whereas attributes as pod size, color and shape are also important for snap bean production. For example flat yellow-podded varieties are highly valued in Spain for fresh market , whereas industry usually demands green rounded pods. In dcry bean the most valuables varieties in Spain are those with large and extra-large white seed (Monteagudo et al., 2000)

Bean germplasm with pod and seed characteristics that permit either the consumption of the fresh pod or the dry seed should be considered as having DCU. Cultivars of this type probably arose from traditional agriculture oriented to local markets and self-consumption in some areas of Europe (De Ron et al., 1990; Zeven et al., 1999; Rodiño, 2001). Advantages for small farmers are clear. They obtain from one crop two different products using their own adapted varieties. Such landraces require less inputs and are often grown in association with maize (Santalla et al., 1994), which contributes to diversified and sustainable on-farm production.

Since commercial uses of beans are clearly distinct, their production in Spain has been conducted by different ways. Dry bean production has dramatically decreased in Spain in the last 10 years ($52 \cdot 10^3$ Mg in 1990 *versus* $19 \cdot 10^3$ Mg in 2000), whereas production of snap bean has increased form $277 \cdot 10^3$ Mg in 1990 to $286 \cdot 10^3$ Mg in 2002 with a market value of $360 \cdot 10^6$ € (MAPYA, 2001).This increase is probably due to the change in human diet, regarding vegetables as healthy food and it is contributing also to benefit farmers.

Major global breeding objectives in common bean concern to the development of cultivars combining high productivity, stable yields, earliness, pest and disease resistance, and tolerance to environmental stresses (Singh, 2001). In the case of dry bean, seed color, shape and size are relevant, whereas regarding to snap bean, marketable pods must be fleshy, tender, and green or yellow. Phenotypic selection by farmers could have maintained together in adapted bean landraces valuable pod and seed attributes that should permit DCU. Regarding productivity some major constraints in this crop are abiotic stresses and diseases in different areas of production (Dursun et al., 2002; Schneider et al., 2001; Singh, 2001; Suzuki et al., 2001). These problems affect bean cultivars independently of their use as snap or dry bean, so both types as well as the possible DCU ones need breeding efforts to overcome those constraints and improve the current yield.

Availability of variation for genetic improvement is a goal for breeders. Bean landraces are often mixtures of lines (Gepts & Bliss, 1986; Kaplan, 1981; Traka_Mavrona et al., 2000) adapted to specific agrosystems after many years of cultivation and conscious or unconscious selection by farmers. Some adapted landraces could be a relevant source of diversity for selection of new lines to be used to enlarge the genetic basis of currently cultivated bean varieties (Singh, 2001), including breeding for different uses. These new lines could contribute to sustainable production by means of low inputs due to the adaptation to specific environments.

A germplasm collection of common bean from Spain and Portugal (Iberian Peninsula) was built at MBG-CSIC (Pontevedra, Spain) since 1987 through several collecting missions and germplasm received from farmers, traders, breeders and gene banks (De Ron et al., 1997). This collection is mandated to actively preserve basic resources for food security, production and plant breeding. In this collection some landraces were incorporated whose associate information gathered from farmers was clear about their use either as snap or dry bean. In some cases no information was available. Many of these bean accessions could have DCU in spite of primary use by farmers as a single product, following local preferences.

In this work we report the evaluation of common bean Spanish landraces under different environments. The objective was to assess the DCU potential of common bean landraces (vegetable and/or grain legume) and their breeding and production possibilities in a sustainable agriculture for different areas of production.

Material and methods

One hundred common bean landraces from Spain (Figure 1) and six elite cultivars were evaluated in 1993 and 1994 in three locations in the North of Spain: Pontevedra (42º 26' N, 8º 38' W, 40 masl, average temperature 14.6 ºC, average annual rainfall 1600 mm), Lalín (42º 36' N, 8º 8' W, 500 masl, average temperature 11.7 ºC, average annual rainfall 1200 mm) and Vitoria (42º 51' N, 2º 40' W, 530 masl, average temperature 11.7 ºC, average annual rainfall 840 mm). The landraces are maintained in the breeding collection at the Misión Biológica de Galicia (MBG-CSIC, Pontevedra, Spain) (De Ron et al., 1997).

Fresh pod characters. During the growing period (17 to 27 days after beginning of flowering in 50 % of the plants), fresh pod quantitative data were taken on five representative plants and values were averaged per accession for the following traits: pod length (exterior distance in millimeters from the pod apex to the top); width (distance in millimeters at right angles to the sutures at the level of the second seed from the apex) (Escribano et al., 1997; De la Cuadra et al., 2001); thickness/width ratio, being thickness the distance between pod sides at the level of the second and third seed from the apex, this relation is named coefficient K and estimates the cross- section shape of the dry pod (Puerta-Romero, 1961; De la Cuadra et al., 2001); pod fiber, evaluated as the presence or absence, with a visual scale from 1 to 5 (1 indicated the absence, to 5 indicated a high-level of presence) and pod weight (expressed in grams).

Dry seed characters. After storage at 5ºC and 50 % of humidity during two months, the following seed traits were evaluated (Escribano et al., 1997; De la Cuadra et al., 2001; Puerta-Romero, 1961): seed dimensions (length, width, and thickness) were measured in ten random seeds per population after drying in a forced draft oven at 80 ºC for 72 hours, expressed in millimeters; dry seed weight (determined on one hundred dry seeds per plot) expressed in grams; proportion of seed coat (%) represented by the relation in weight between coat and cotyledon plus seed coat, after removing the seed coat from the cotyledon, after soaking and keeping them for 24 h at 105 ºC; water absorption (%), reflecting the amount of water dried seeds absorb during soaking and determined by soaking 100 dry seeds for 18 hours in water at room temperature and dividing the difference in weight before and after soaking by the dry weight of the 100-seed sample. Crude protein (%) was determined on dried seeds using the Near Infrared Transmittance (NIT) method, being a rapid and non-destructive technique (Williams et al., 1978).

Additionally, growth habit, pod curvature, and pod beak position and shape were recorded (CIAT, 1984). Evaluation of such attributes together with pod and seed quantitative traits should help to assign a landrace to a particular use.

Statistical analyses. Fresh pod and dry seed quantitative characters were analyzed by principal component analysis performed by means of the NTSYS-pc package (Rohlf, 2000).

Results and discussion

Table 1 shows variation in some attributes relevant to the use of the common bean landraces studied for their dry seed or fresh pod, including the DCU. Fifty per cent of the landraces had growth habit type 4 (CIAT, 1984) which reflects the common practice in the Northwest of Spain of intercropping of climbing bean types with maize. Besides, the harvest of snap bean types is commonly made by hand being preferred by farmers the climbing types grown with trellis support. The presence of fiber in the fresh pod in highly variable in the landraces that supports the existence of dry bean types together with snap bean types and DCU ones. Consumers in Spain usually demand straight pods and they prefer also central located straight beaks in pods and regarding to dry seed there is a strong preference in Spain towards large and extra-large seeded types (De Ron, 2001).The results here reported indicate wide variation in these attributes in the 100 landraces studied. It means that on-farm selection by farmers has been effective in breeding adapted varieties that could be used as dry seed, fresh pod of both (DCU).

Principal component analysis shows the distribution of landraces along the axis 1 (first principal component) and 3 (third principal component) that explain, respectively, 31.0 % and 14.4 % of the total variation (Figure 2). Axis 1 represents variation in seed traits (100-seeds weight and seed dimensions), whereas axis 3 displays variation in pod traits (pod length and weight, and pod fiber) as well as in two seed quality traits (seed coat proportion and seed protein content). Ordination of landraces in the plot seems to be reliable according to the location of some of them well-known as traditional dry bean types that should be regarded as reference: extra-large and large seeded accessions belonging to the market classes favada and large great northern

(Santalla et al., 2001) plotted at the positive end of axis 1, whereas small to medium seeded accessions (market classes navy, small white, black turtle and some great northern and white kidney) are located at the negative beginning and middle of axis 1.

Previous knowledge of germplasm is highly relevant to define the classification of bean landraces according to morphological and agronomic traits. In this case, analysis of the data of previous evaluations of Spanish germplasm (De Ron et al., 1990; Escribano, 1992) together with the database of the bean collection at the MBG-CSIC (data not published) and the information gathered from farmers determined that 11 accessions evaluated were used by farmers as a vegetable for their fresh pods. They were included in the Group 1. An additional seven accessions were primarily recorded as dry seed cultivars that plotted inside the Group 1 and were named as Group 1B. Two landraces with possible DCU, showing rounded pods, were assigned to Group 2. Other accessions close to these groups were not candidates for snap bean or DCU because their values for a key trait such as pod fiber were too high. From the point of view of bean improvement, the DCU adapted bean landraces could be a relevant source of diversity for selection of new, improved, adapted cultivars for sustainable production in farmers fields.

Table 2 shows the evaluation data of the 20 bean accessions included in the groups 1, 1B and 2, the seed and pod type, and the mean and range of variation of the quantitative traits in the overal sample of 106 accessions. Green or yellow flat pod type is the most common and only two accessions had a rounded pod type, which is a reflection of market preferences in Spain. Regarding seed type, the landraces evaluated presented types of seed belonging to different market classes (Santalla et al., 2001).

Snap bean accessions included in Group 1 and Group 2 displayed values for seed traits (i. e. water absorption, seed coat proportion) quite similar to the average of the sample of 106 accessions. On the other hand, dry bean accessions belonging to Group 1B showed adequate scores in pod traits (i. e. pod fiber, pod length) to be used also as snap beans. This fact indicates that farmers have the possibility for using the landraces of groups 1, 1B and 2 as snap beans and also as dry beans if needed, perhaps under uncommon circumstances. The landraces show some types of seed often present in traditional recipes in some areas of Spain, e. g. negro brillante, caparron, morado and cranberry. The bean germplasm of these groups here described could be the result of a process of phenotypic selection by farmers to optimize the use of their natural resources for diversified food uses. The overall averages of the 106 accessions evaluated for the pod and seed traits indicate that most of them should be used for dry bean consumption based in the observed pod fiber.

The close proximity of smallholdings in the Northwest of Spain contributes to outcrossing and seed exchange among bean landraces as already documented by Ibarra-Pérez et al. (2000), Rodiño (2001) and Zeven et al. (1999). This exchange would result in groups of bean landraces with mixed characteristics often displaying double-use. The secondary diversification of the species in southwestern Europe documented by Santalla et al. (2002) could have played a role in these processess.

Special attention deserves a group of landraces from La Bañeza (León) (Figure 1) where there is an ancient costume of growing dry bean: PHA-0597, PHA-0606, PHA-0614 (Group 1) and PHA-0602, PHA-0604 and PHA-0612 (Group 1B). They displayed appropriated values for pod traits to be used as snap bean and it could be an example to demonstrate on-farm selection. This fact perhaps together with genetic drift would have resulted in successful DCU varieties with a chance for the improvement of common bean cultivated varieties adapted to specific agrosystems.

There is strong evidence that supports the primitive use of common bean as dry seed being a relevant source of protein in the human diet in America and later on in Africa and Europe. The ancient landraces had probably highly fibrous pods that resembled the wild ones, which implies some degree of pod dehiscence (Menéndez-Sevillano, 2002). The presence of pod fiber is controlled by few genes (Bassett, 2003). Conscious selection by men as well as genetic drift could have been evolutionary forces responsible for low-fibre pods in dry bean cultivars, which developed DCU potential (Myers and Baggett, 1999). Later on, farmers were supposed to maintain these adapted varieties on their own. Outcrossing (Ibarra-Pérez et al., 2000) and seed exchange among farmers (Zeven, 1999) were relevant factors in this process. Some farmers consumed DCU bean varieties, which contributed to a healthy human diet in two different ways: as a vegetable (source of fiber, vitamins and minerals) and a grain legume (main source of protein) (Willet et al., 1995; Champ, 2002).

Little has been written on what procedures snap breeders use, particularly in private programs (Myers and Baggett, 1999). Usually, breeders continue to make single selections into advanced generations to achieve the high degree of uniformity required in a released snap bean cultivar. The disadvantage is that by selecting traits with high heritability in early generations, genetic variation with low heritability is lost (Fouilloux and Bannerot, 1988). This fact emphasizes the need for enlarge the genetic basis of snap bean germplasm incorporating new adapted sources of variation to breeding programs focussed to obtain improved varieties for specific areas of production.

Adaptation of DCU cultivars to areas of production requiring sustainable production should be a goal for breeders and farmers. The bean landraces of groups 1, 1B and 2 with pod and seed profitable characteristics documented in this work could be a starting point for that objective. Small farmers, mainly in the Northern regions of Spain could benefit from adapted bean germplasm to improve pod traits to release new snap bean cultivars for fresh market. Besides, large scale production in the southern areas should incorporate new sources of variation such as the DCU landraces here documented in their snap bean breeding programs.

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Table 1. Plant, pod and seed attributes of the 100 bean landraces studied.

Growth habit					
I	*II*	*III*	*IV*		
30	11	9	50		
Pod fibre					
1	*2*	*3*	*4*	*5*	
16	17	21	42	4	
Pod curvature		Pod beak position		Pod beak shape	
Straight	*Curved*	*Placental*	*Central*	*Straight*	*Curved*
92	8	49	51	24	76

Seed size

Small (<25 g 100 seeds)	*Medium* (25-40 g/100 seeds)	*Large* (>40 g 100 seeds)
2	10	88

Table 2. Average for the pod and seed traits of the common bean landraces included in groups 1, 1B and 2.

Accessions	PF (1)	PL	PW	PTW	100-SW	SWA	SL	SW	ST	SCP	SPC	Seed type	Pod type
GROUP 1													
PHA-0192	1.33	113.7	13.68	0.43	52.1	55.4	11.15	8.60	7.16	6.82	36.5	Negro brillante	Flat, yellow
PHA-0193	1.5	170.3	13.33	0.45	71.4	95.3	15.83	8.65	6.93	7.03	30.3	Dark garbanzo	Flat, yellow
PHA-0272	1.18	119.4	14.96	0.35	45.4	33.9	11.86	8.34	6.40	6.60	34.4	Purple caparron	Flat, yellow
PHA-0300	1.42	165.4	13.55	0.45	71.0	97.3	16.14	8.68	6.94	7.07	32.6	Ligth red kidney	Flat, green
PHA-0331	1.5	118.2	13.60	0.44	64.2	100.5	10.98	8.93	7.94	6.26	32.4	Rounded caparron	Flat, green
PHA-0382	1.5	124.5	13.75	0.36	65.9	98.6	14.95	8.69	6.58	7.20	31.6	Azufrado	Flat, green
PHA-0385	1.17	120.9	13.75	0.44	58.9	93.1	10.73	8.85	7.83	6.19	32.6	Rounded caparron	Flat, green
PHA-0453	1.45	107.7	14.60	0.38	74.3	80.5	13.48	9.60	7.98	6.98	30.3	Morado	Flat, yellow
PHA-0597	1.25	180.8	13.10	0.44	63.6	100.3	15.18	8.41	6.88	8.03	35.4	Brown garbanzo	Flat, yellow
PHA-0606	1.83	155.7	13.69	0.46	55.1	94.9	13.62	8.28	6.75	7.40	29.5	Sangretoro	Flat, green
PHA-0614	1.58	193.9	15.82	0.33	43.6	123.1	13.73	7.93	5.39	7.72	30.8	Marrow	Flat, green
Mean	*1.43*	*142.8*	*13.98*	*0.41*	*60.5*	*88.4*	*13.42*	*8.63*	*6.98*	*7.03*	*32.4*		
GROUP 1B													

PHA-0112	2.33	137.9	13.08	0.47	66.8	89.1	15.39	8.49	6.59	8.68	30.4	Azufrado	Flat, green
PHA-0212	1.09	113.3	14.90	0.46	57.2	88.8	12.38	9.08	7.10	6.94	31.9	Brown garbanzo	Flat, green
PHA-0230	1.58	157.0	13.00	0.47	73.9	94.9	16.40	8.99	6.98	7.35	33.3	Dark garbanzo	Flat, green
PHA-0596	1.33	106.4	13.57	0.47	61.0	96.9	13.24	9.30	7.19	7.45	31.0	Cranberry	Flat, green
PHA-0602	1.58	163.8	12.55	0.47	63.7	90.6	14.99	8.41	6.70	7.70	29.9	Rosada	Flat, green
PHA-0604	1.58	155.0	13.33	0.46	67.3	95.9	15.96	8.68	6.79	7.73	28.9	Brown garbanzo	Flat, green
PHA-0612	1.67	135.7	15.19	0.40	61.2	101.9	14.73	8.56	6.65	6.87	34.3	Ojo de cabra	Flat, green
Mean	*1.6*	*138.4*	*13.66*	*0.46*	*64.5*	*94.0*	*14.73*	*8.79*	*6.86*	*7.53*	*31.4*		
GROUP 2													
PHA-0131	1.33	145.7	9.21	0.91	43.0	110.9	14.21	6.75	5.84	7.92	33.0	Canellini	Green, rounded
PHA-0168	1	147.3	9.37	0.81	50.0	103.1	16.54	7.03	5.98	8.56	31.8	Sargaço	Green, rounded
Mean	*1.17*	*146.5*	*9.29*	*0.86*	*46.5*	*107.0*	*15.38*	*6.89*	*5.91*	*8.24*	*32.4*		
Mean 1, 1B, 2	1.46	141.6	13.40	0.47	60.5	92.2	14.07	8.51	6.83	7.33	32.0		
Overall mean	2.96	121.6	12.40	0.47	58.8	97.3	14.19	8.19	6.29	7.33	30.0		
SE	0.105	3.54	0.33	0.01	2.16	3.79	0.26	0.12	0.108	0.377	0.31		
Maximun	4.7	193.9	15.80	0.91	112.9	130.1	20.58	9.78	8.03	9.29	40.8		
Minimum	1	75.7	9.20	0.29	16.2	32	7.74	5.61	4.62	5.83	24.1		

(1) PF: pod fiber; PL: pod length; PW: pod width; PTW: pod thickness/width; 100-SW: 100-seeds weight; SWA: seed water absorption; SL: seed length; SW: seed width; ST: seed thickness; SCP: seed coat proportion; SPC: seed protein content

Figure 1. Geographical origin of the common bean landraces evaluated with indication of the number of landraces from each Spanish region (* indicates: La Bañeza, Castilla y León).

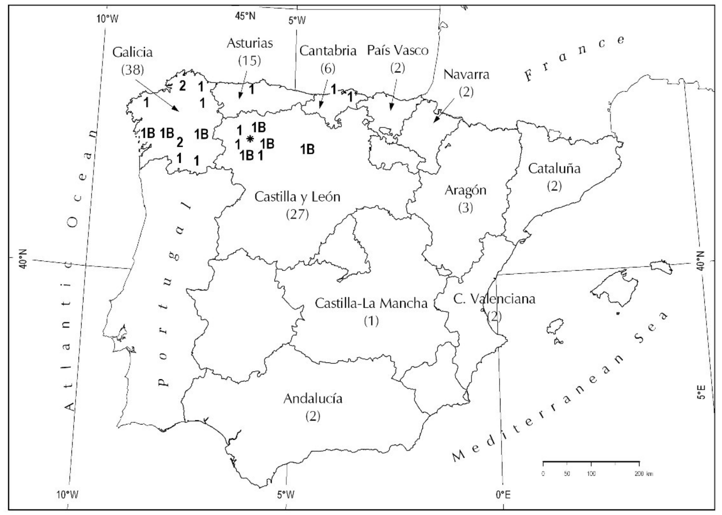

Figure 2. Ordination of the common bean accessions studied along the first (PC 1) and third (PC 3) principal components. Groups 1 and 2 are indicated (G 1, G 2) and landraces belonging to group 1B are inside squares (numbers in the plot plus PHA- indicate the code of the accessions as in Table 2. Elite cultivars: ALB - Alba; GAN - Ganxet; GN - Great Northern; MID - Midland; TAY - Taylors; WK - White Kidney)